Fuel Cells:

A Technology & Applications Overview

Presented by:

Malcolm Jacobson, Principal

Strategic Clean Energy, LLC

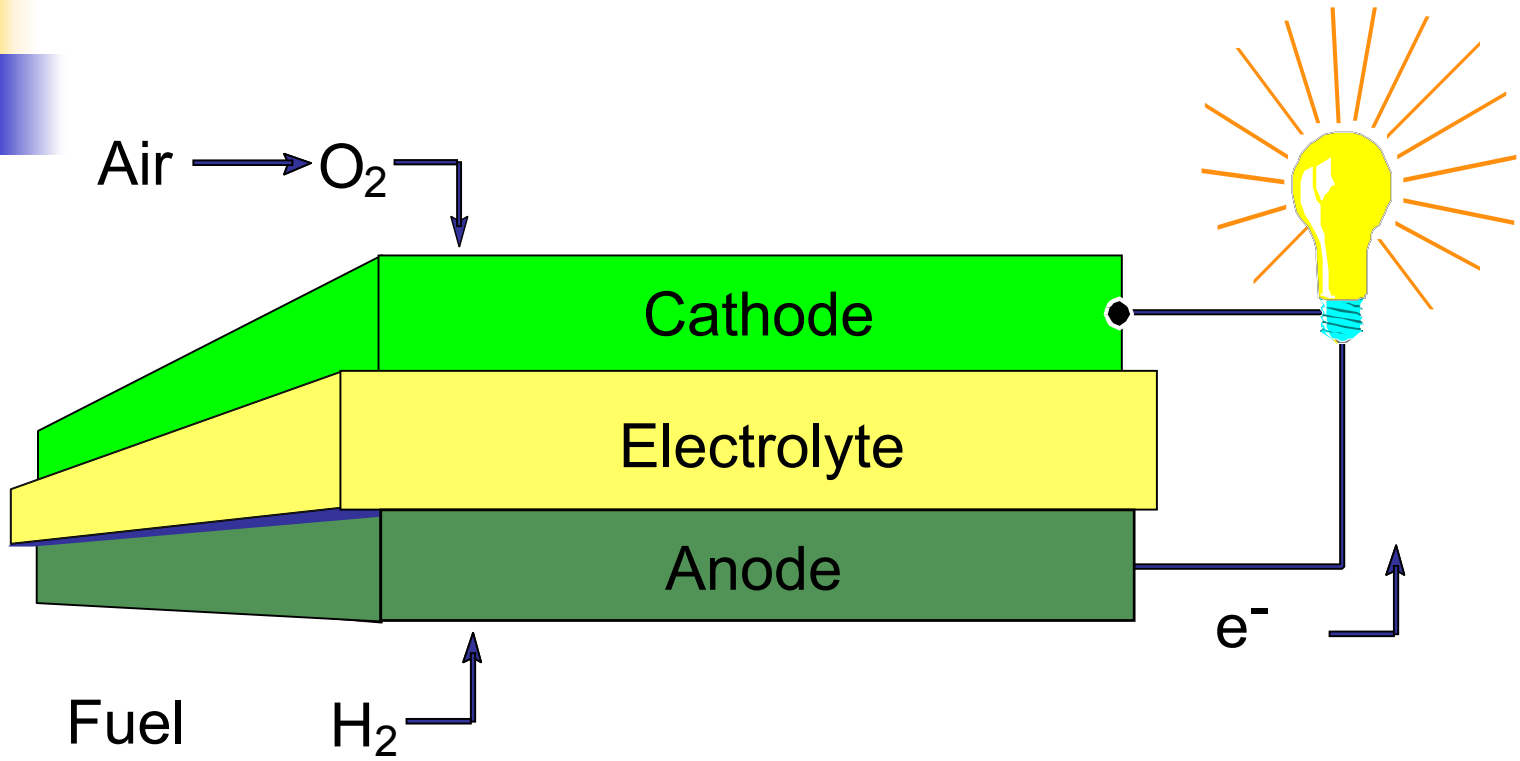
Who is Strategic Clean Energy?

- Newly formed in 2003 to advance commercial application of clean energy technologies
- Dedicated exclusively to the clean energy industry
- Publish the *Clean Energy Outlook* ™
- Provide consulting services
  - *Market intelligence*
  - *Analysis and planning*
  - *Project development*

Overview

- Fuel Cell Technology Primer
  - The Fuel Cell Concept
  - Types of Fuel Cells
  - Fuel Cell Systems
  - Operating Characteristics
- Applications
- Project Considerations
  - Technical Screening
  - Codes & Standards
  - Economics
- Texas Fuel Cell Initiatives
- Q&A

What is a "Fuel Cell"?



- Electrochemical process – No combustion
- Direct conversion to electricity
- Generic chemical reaction: 2H2 + O2 ⟶ 2H2O + electricity + heat
- Continuous as long as Air (O2) & fuel are provided

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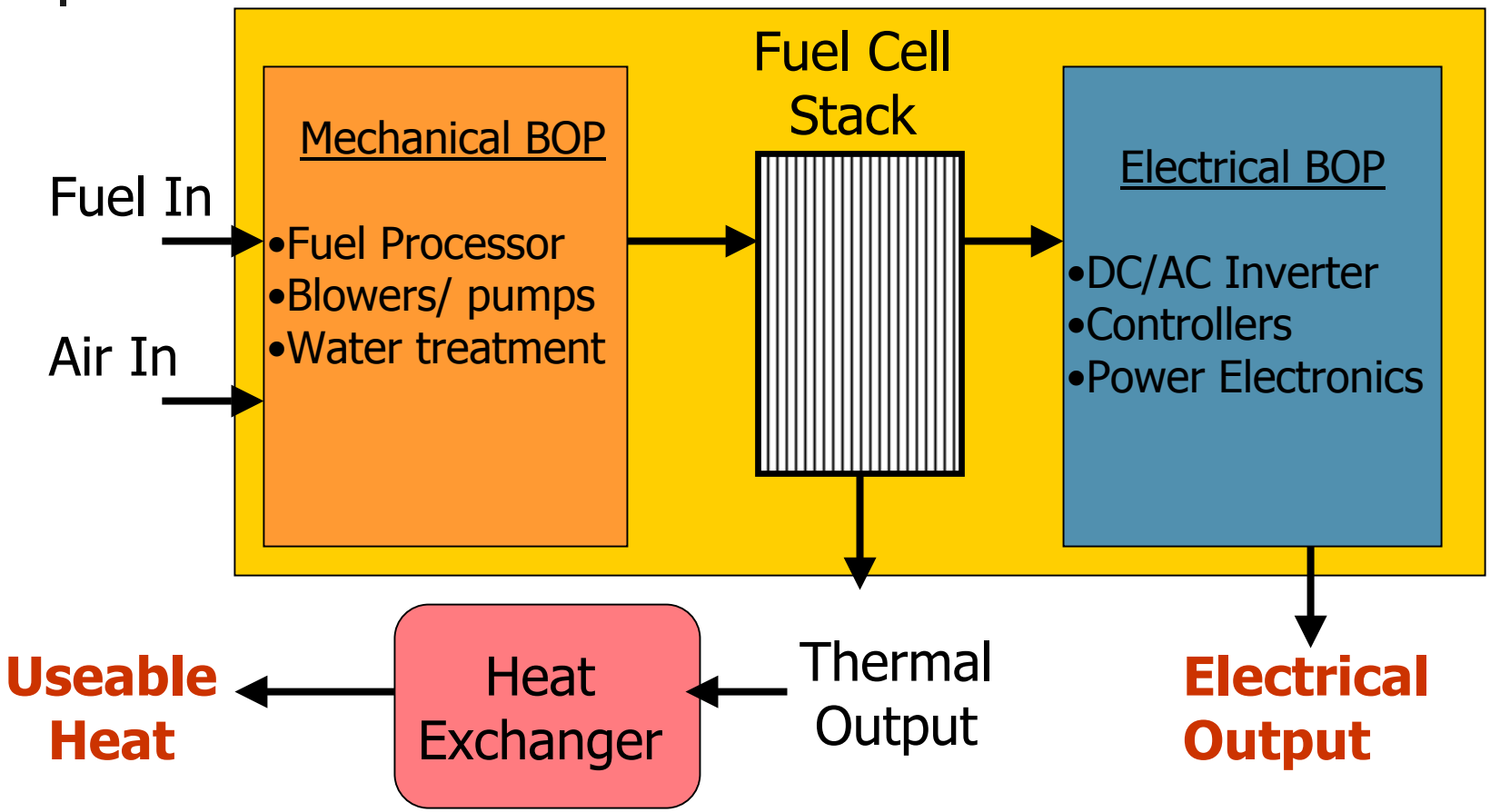
Five Distinct Types of Fuel Cells

TYPE	OPERATING TEMP.	ELECTRICAL EFFICIENCY	PRIMARY APPLICATIONS
Alkaline	50 – 200 °C	Low	Space shuttle
Proton Exchange (PEM)	50 – 100 °C	30 – 35%	Vehicles, portable, residential
Phosphoric Acid	200 - 220 °C	35 – 40%	Commercial/ Industrial
Molten Carbonate	600 - 700 °C	47 – 52%	Commercial/ Industrial/ Utility
Solid Oxide	500 –1000 °C	42 – 47%	Wide range: Portable -> Large Stationary

Integrated Fuel Cell Power Plant



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A Wide Array of Fuel Cell Power Plants

Photo Courtesy of FuelCell Energy, Inc.


Photo Courtesy of UTC Fuel Cells


Photo Courtesy of FuelCell Energy, Inc.

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Why Fuel Cells?

Operating Characteristics Yield Practical Benefits…

- High Energy Conversion Efficiency
  - Reduces fuel cost per kWh by up to 50% vs. conventional generators
  - Co-generated heat provides add'l savings
- Environmental Characteristics
  - Virtually non-polluting
  - Unobtrusive and quiet
- Siting Flexibility
  - Uniquely suited for placement at or near load points
  - Modularity allows incremental deployment
  - Minimal "NIMBY" and safety concerns

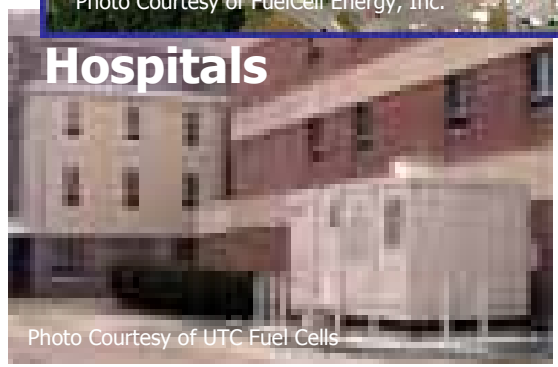
Why Fuel Cells? (cont'd)

Operating Characteristics Yield Practical Benefits…

- Reliability
  - No moving parts in a fuel cell stack
  - Minimizes O&M costs
  - Reduces cost of unscheduled down time
- Premium Power
  - Highly conditioned AC power output suitable for sensitive digital equipment
  - Can be a key component of a "high 9's" premium power system

Stationary Applications

Today's High-Value Applications for Fuel Cells



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Anatomy of a Successful Project

Practical Considerations

- **Technical Compatibility**
  - Electric load profile
  - Thermal host
  - Site preparation/ interconnection reqm'ts
- **Compliance with Codes and Standards**
- **Economic Viability**
  - Availability of funding
  - Existing energy rates/ fuel cost
  - Contract terms / risk mitigation
  - Ability to monetize emissions credits
  - Reliability/ premium power value

Product Standards

- **ANSI Z21.83** - Standard on Fuel Cell Power Plants. Scope includes stationary FCS. Currently addresses natural gas and propane fueled systems.

- **ANSI CSA FC 1** - This proposed standard will replace Z21.83 and be broadened to include most types of fuels, gas and liquid, hydrocarbons and alcohols. Latest ballots submitted May 15, 2003.

- **ANSI CSA FC 3 -** Draft Portable Fuel Cell Power Generators. Scope includes portable FCS.

Used to Certify Equipment – Not installations

Installation Standards

- **NFPA 70** - National Electrical Code, Article 692
- **NFPA 54** – National Fuel Gas Code
- **NFPA 31** – Installation of Oil-Burning Equipment
- **NFPA 853** – Installation of Stationary Fuel Cell Power Plants. The scope of this standard is for FCS exceeding 50 kW. Work is in progress to revise this standard to include all Stationary Systems (removes the 50 kW clause). Report on Proposal for updated version issued May, 2003.

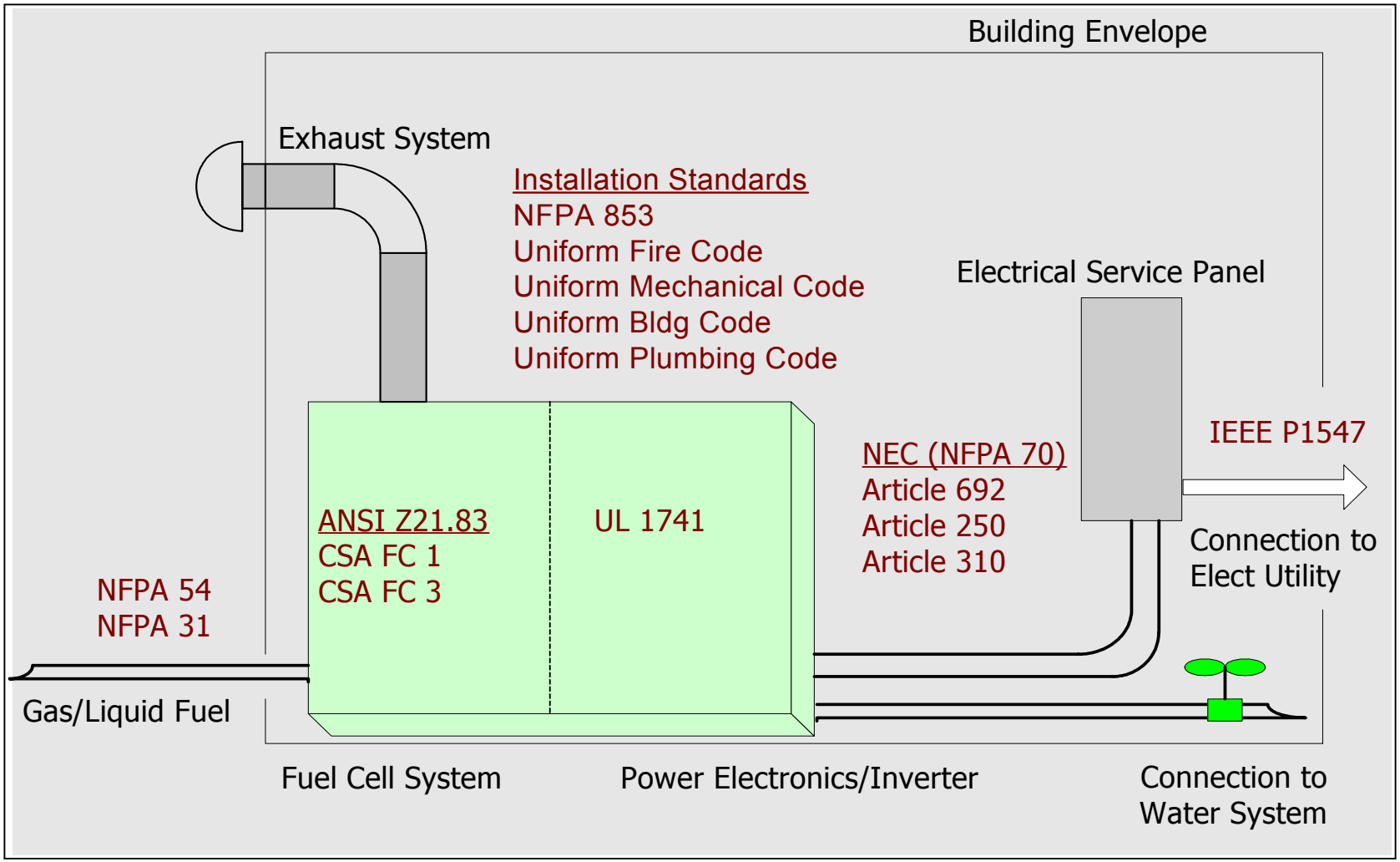
Electrical Interconnection

- **UL 1741** – Standard for Inverters, Converters, and Controllers for use in Independent Power Systems. Scope includes both Grid-Tied and Grid Independent systems.
- **IEEE P 1547** – Standard for Interconnecting Distributed Resources with Electric Power Systems.

- In the future these two standards could be harmonized, and the work done in P1547 may be adopted into UL 1741.

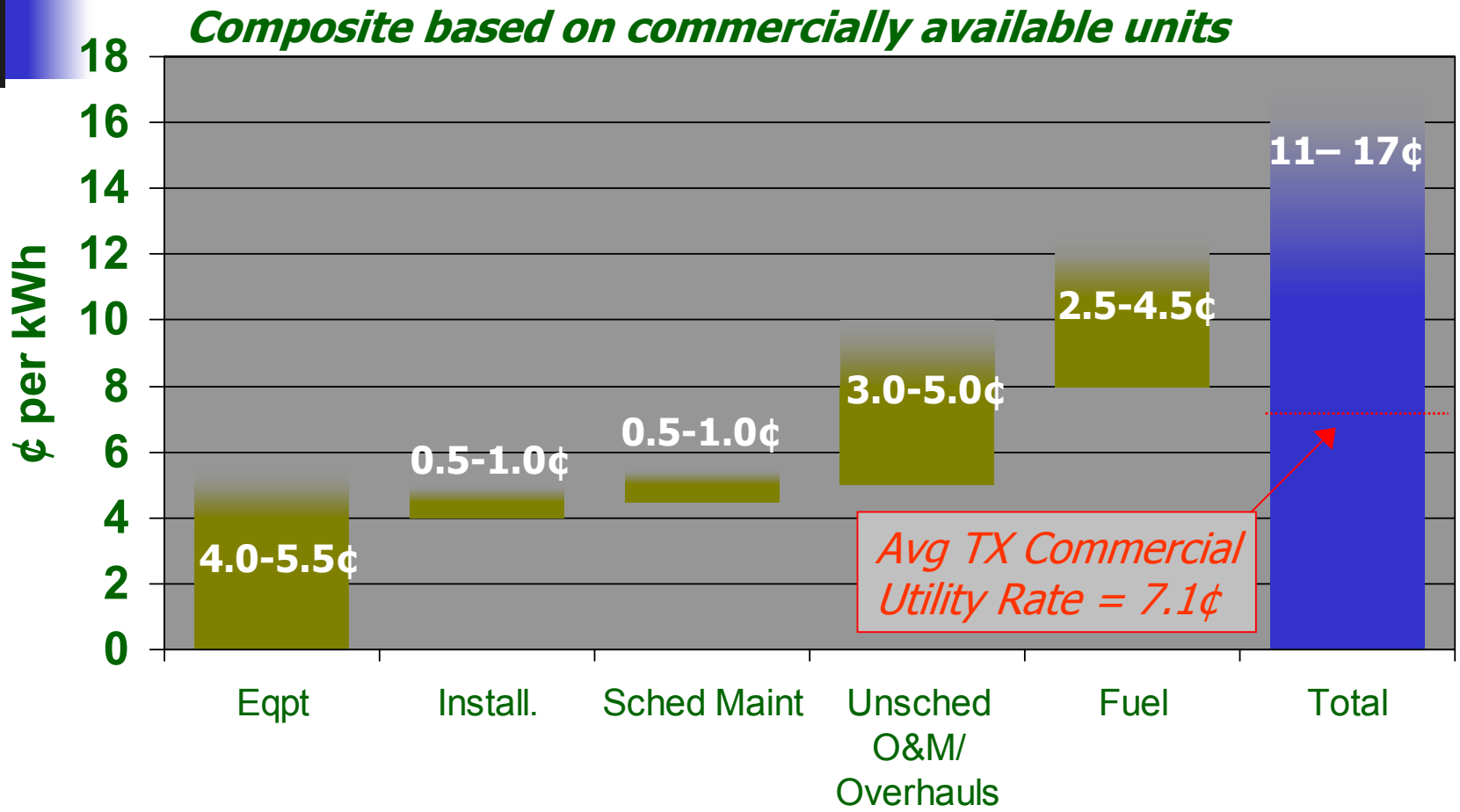
Summary of Applicable Codes/Standards

Stationary Fuel Cell System



A Snapshot of Fuel Cell Economics

"Raw" Cost of Electricity Not Yet Competitive



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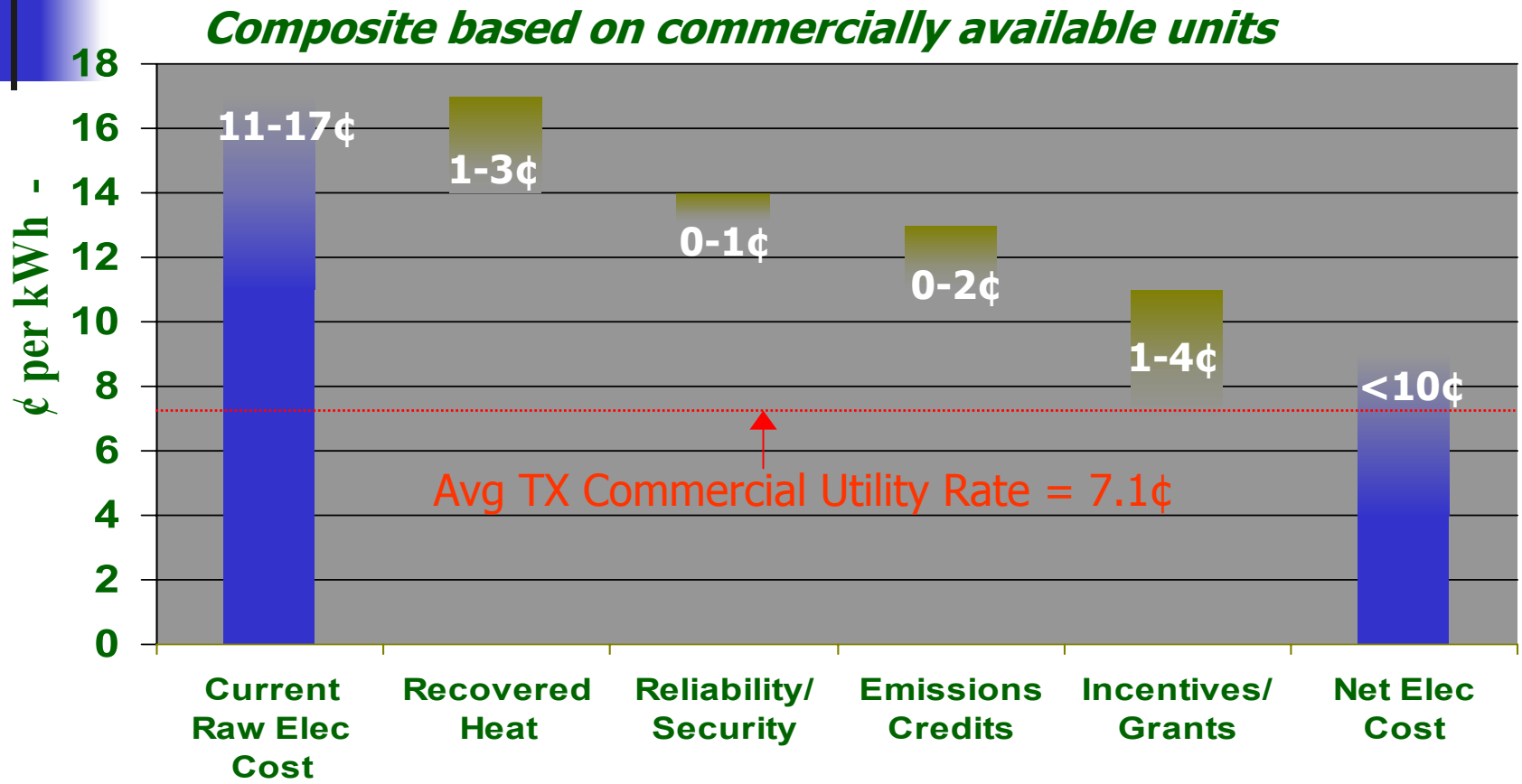
Fuel Cell Projects Can Be Viable Today

Application/Site Selection and Subsidy Funding Are Key



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Texas Update

Significant Commercialization Efforts Underway

- **2003 Legislative Proposals**
  - Fuel cell funding through TX Emissions Reduction Plan (Administered through TCEQ)
  - Sales tax exemption for fuel cells
  - Directive for State Energy Office to pursue federal funds
- **Public Utility Commission Initiative**
  - White Paper issued Aug'02 proposes production incentives to promote fuel cell deployment
  - Likely to be addressed in ongoing restructuring proceedings
- **State Energy Conservation Office Efforts**
  - Facilitator of Fuel Cell Initiative/ Conduit for federal funds
  - *Fuel Cell Commercialization Plan* submitted to Legislature Sept, 2002 recommended market incentives to spur deployment of 1,000 MW of fuel cells in TX by 2011.

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Contact Information

Principals:

Malcolm Jacobson
Tel: (281) 356-4043

David Glover
Tel: (281) 292-9329

E-mail:
Info@StrategicCleanEnergy.com